3D RECONSTRUCTION AND MORPHOLOGICAL QUANTIZATION OF A HUMAN EMBRYO HEART FOR THE VALIDATION OF A VIRTUAL MODEL

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Abstract - **This paper will present the methodology used for the reconstruction of a human 13 Weeks of Age (WOA) embryo heart. This reconstructed heart is visualized and some quantitative measurements are performed in order to allow the validation of a virtual computer generated heart model.**
Keywords – **Human embryo heart, 3D reconstruction, visualization, embryology.**

I. INTRODUCTION

This paper presents a part of a more global project concerning the teaching of the heart development. The learning of the cardiac embryology is a difficult task, as it requires perceiving the constitution, the spatial development and the function of many complex anatomical structures. In order to help the students (and also the teacher), we developed a Computed Aided Teaching support where the main component is a 3D animated sequence of the overall embryogenesis process of a normal heart, this from the fecundation until its final form [1]. Due to the complexity of the morphology and the high difficulties to acquire real images from an embryonic human heart, this animation has been designed as 3D synthetic images by help of computer graphics. The 3D forms have been extrapolated from two-dimensional representations available in the existing literature [2]. The goal of the present paper is the validation of the geometry of these virtual heart volumes. For this we will try to reconstruct the real volume of a 13 Weeks of Age (WOA) embryonic heart. The visualization and measurement performed on this cardiac volume will help us to validate the model in terms of size, thickness and precise position of the several cardiac structures: ventricles, atria and large vessels.

II. HEART RECONSTRUCTION METHODOLOGY

Acquisition of the heart

A heart of a human embryo has been obtained by a selective collection during a voluntary termination. The size of a 13-WOA embryonic heart is around 6 mm high. This size is to big for confocal microscopy and to small for CT. So no real 3D acquisition can be directly performed. In our methodology, the cardiac block is fixed in a 10% formaldehyde solution and then included in paraffin. The volume is then entirely sliced on a microtom in serial 10 µm thick sections from the apex to the top. One slice out of 10 receives a topographic coloration with H. E. S. (Hemalum, eosin, and saffron). The colored slices are digitized on an optical microscope (IKAROS 3 V 4.33 from Metasystems) (figure1).
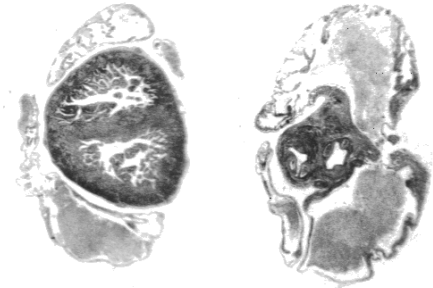

Figure 1: two slices of the 13-WOA embryonic heart. On the left the ventricles surrounded by some atria parts can be seen. On the right, the slice goes through the atria, the aorta and the pulmonary artery. The pulmonary and aortic valves can be seen in the middle of the vessels. Notice the several blood clots within the atria.

Image processing

The image processing follows the several steps:
1) Preprocessing. A scale inversion is first performed followed by a noise reduction using a median filter.
2) Registration. Due the acquisition methodology, the heart sections have not a fixed position over the several slices. We use a half-automatic matching technique in order to align the slices. A) Under the assumption that the sections are not deformed (this is only partially true because the microtom distorts the slice during the cut) a automatic rigid registration method based on the geometrical moments allows to pre-arrange the volume. B) The misalignments due to the deformations are then manually corrected using an interactive own-developed rigid fitting package.
3) Segmentation and labeling. The goal of this step is to isolate the ventricles, the atria and the two large vessels, the aorta and the pulmonary artery. Due to the properties of the structures in the images (complex shapes, no real differences in values between the structures, fusion between the structures, deformation of the thin atria wall, blood clots, etc.), we choose to use a manual segmentation and labeling technique (figure 2).
4) Calibration. The inter-slice distance is know (100 µm). In order to estimate the image resolution, we digitized, a scale graduated in mm on one of an image during the acquisition process.
5) Volume formation. A voxel volume is reconstructed by simply stacking the sections. An isotropic volume is obtained by a resampling along the stack direction according to the calibration results (spline based interpolation).

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Abstract

Subject Terms

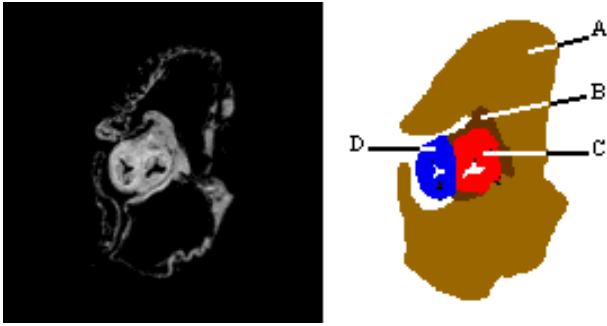|	
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Figure2: segmentation and labeling of the heart structures. A) Atria, B) ventricles, C) Aorta and D) pulmonary artery.

III. VISUALIZATION AND MEASUREMENTS

Visualization

The cardiac volume can first be studied by using a 3D-visualization tool showing the internal and the external areas of the heart. We use two ways to explore the heart volume:

- The visualization of the volume on 3 perpendicular user-defined slices (figure 3) allows to specify the morphology and spatial relationship of some anatomical structures (e.g. valves and papillary muscles).
- 3D visualization. For this we use a volume rendering Ray-Casting based method which allows to directly visualizing the surfaces within the voxel volume without any prior surface extraction [3]. It is thus possible to perceive the size, thickness and relative position of the several cardiac structures in terms of both external and internal morphologies (figure 4).
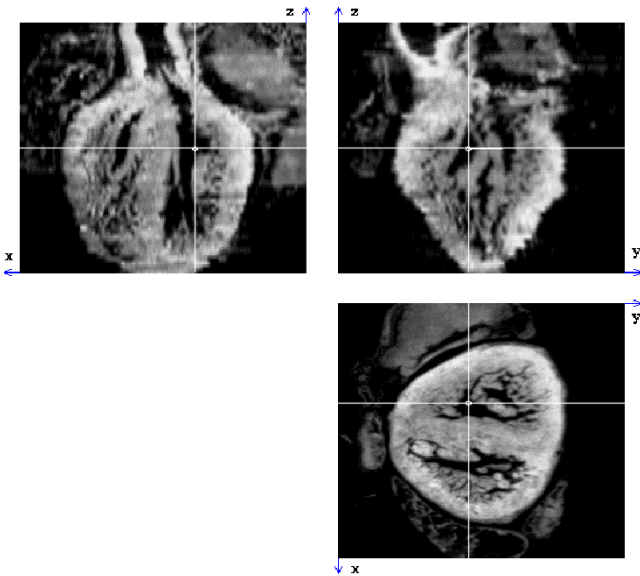

Figure 3: Perpendicular planes through the volume. Notice the perpendicular view of the aortic semilunar valves on the top left slice.

Measurements

The segmentation and the calibration steps allow also extracting some measurements about the heart volume. For example, on the 13 WOA heart, the volume of the ventricles is estimate about 28.5 mm^2 and this of the atria about 40.2 mm^2. This proportion can be surprising related to an adult heart but confirms some hypotheses of the cardiac embryology.
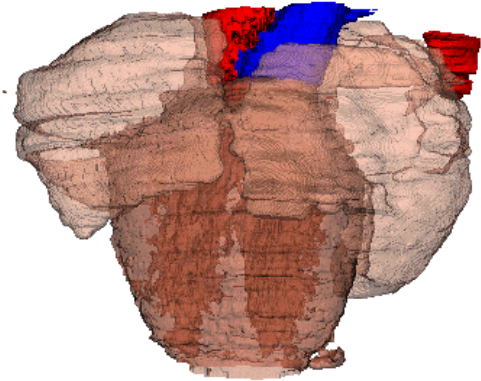

Figure 4: 3D volume rendering of the reconstructed volume. The inner surfaces are seen by transparency.

IV. DISCUSSION

The methodology presented in this paper is only a first framework of the reconstruction of the embryonic cardiac volumes. New improvements can be applied on most of the steps. During the acquisition, external landmarks could facilitate the registration. New methods have to be imagined to avoid deformation of the slice during the cutting. The digitization must be improved and automated. Some image processing steps must also be more automated. However, this method can be extended to embryos at an earlier stage (8 to 5 WAO). So it will allow studying the spatial and the time development of the cardiac structures. It can also be applied on other embryonic structures or for the reconstruction of the whole embryo.

V. CONCLUSION

This new reconstruction and visualisation method makes it possible to validate models based on synthetic images. It can be used regardless of the size of embryonic hearts. So its implementation at earlier stages of embryogenesis will provide a clearer view of cardiac development.

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